Can continuously recorded waveform data be improved with signal processing? Application of deconvolution to microseismic data

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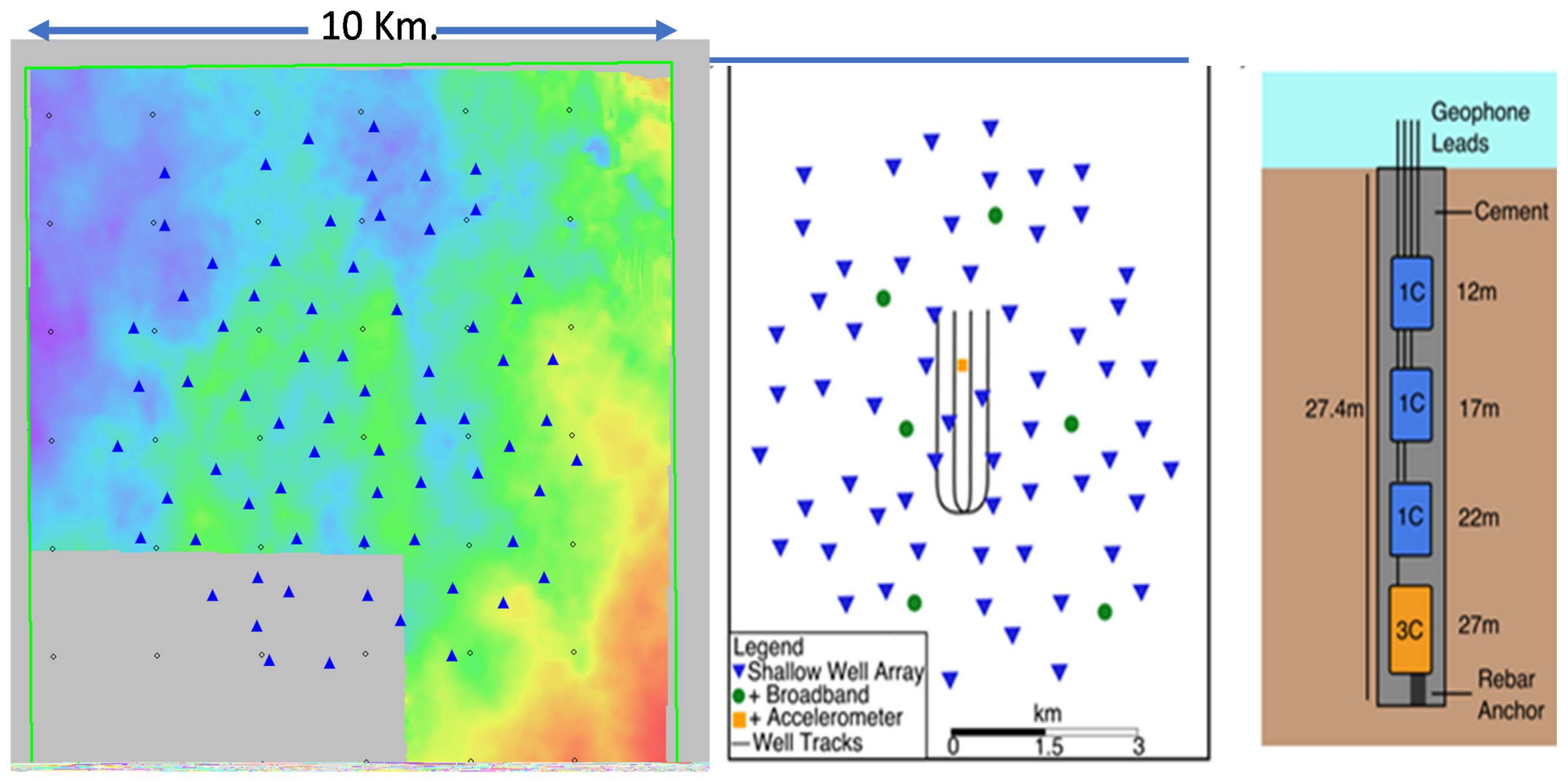
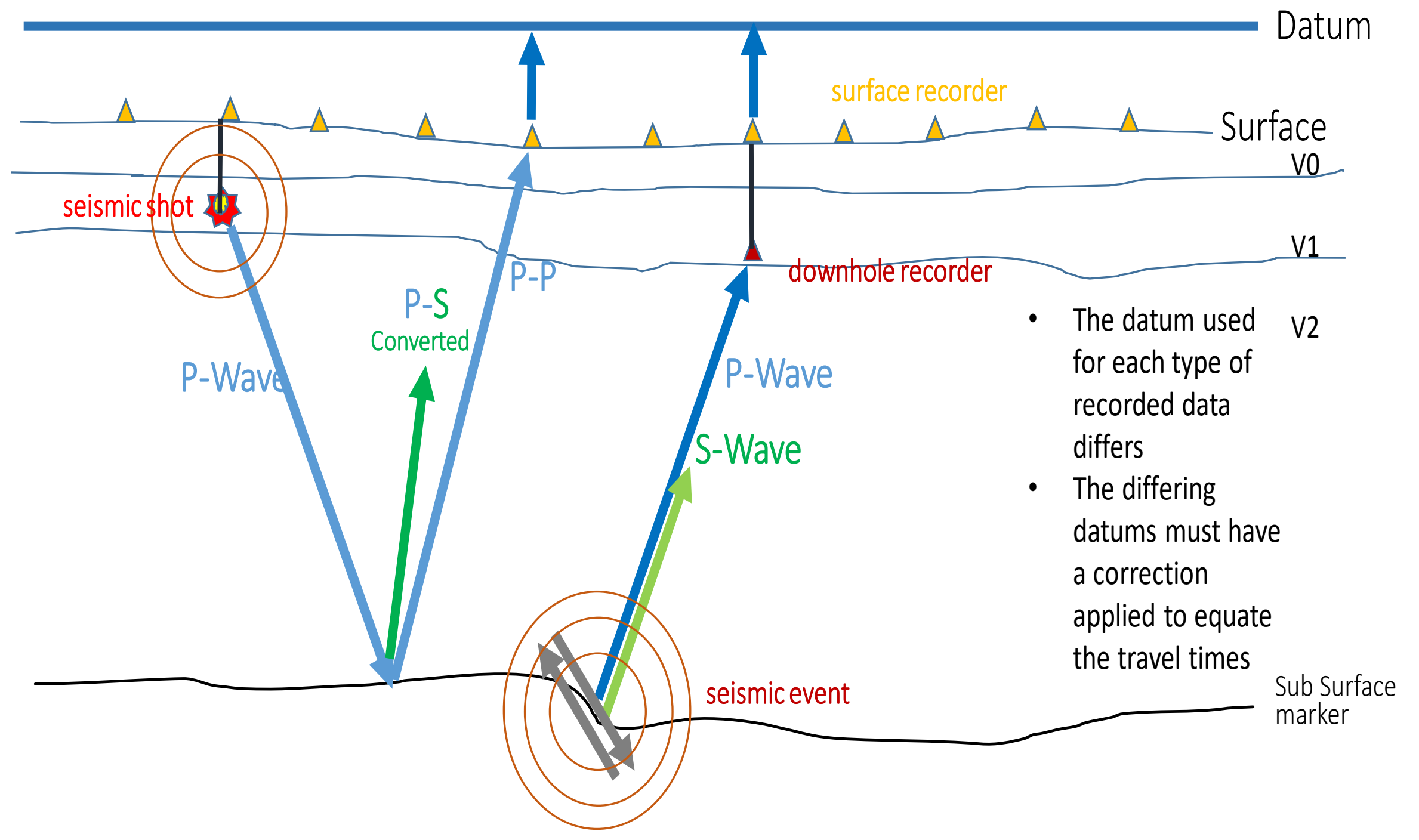
Passive seismic recording is increasingly being used to record seismic events associated with hydraulic fracture stimulation. The recorded amplitudes of these induced seismic events are relatively weak, and may be undetectable given the noisy environment in which they are recorded. Signal processing has been used for many years in reflection seismic data to enhance signal quality. Algorithms such as deconvolution, scaling, and various types of filtering have been routinely applied to raw recorded data to enhance the processing and interpretability of the recorded data. In this study we apply a combination of the more commonly used algorithms used in reflection data processing to continuously recorded microseismic data and demonstrate how signal quality can be improved. These results demonstrate how signal processing can lead to more reliable detection of induced seismic events, and significantly improve the overall signal quality.

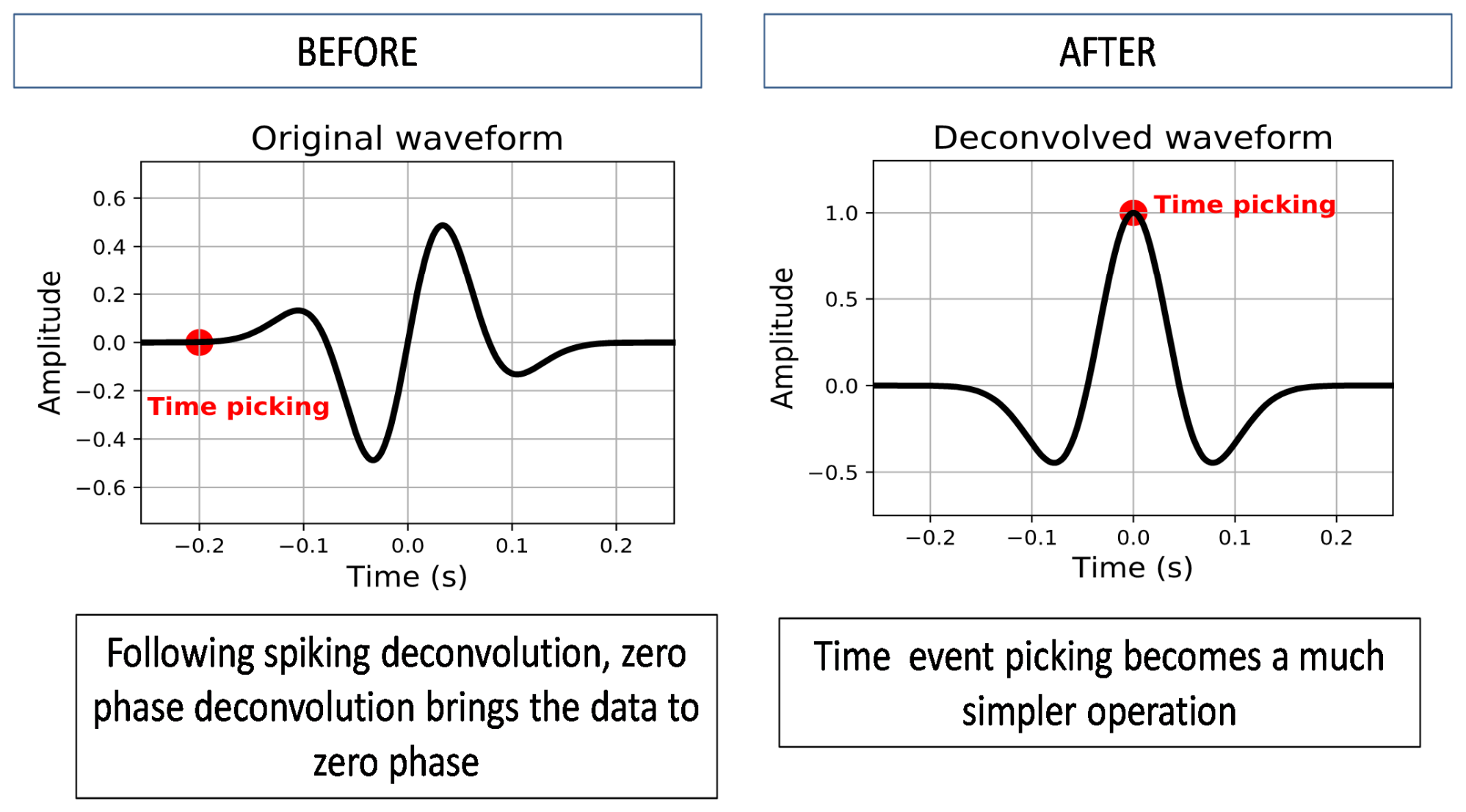


The location and configuration of the passive recording array. Most of the TOC2ME passive recording stations are co-located with the 3-D, 3-C seismic program. The time structure map shown outlines the extent of the 3-D survey.



- The datum used for each type of recorded data differs
- The differing datums must have a correction applied to equate the travel times

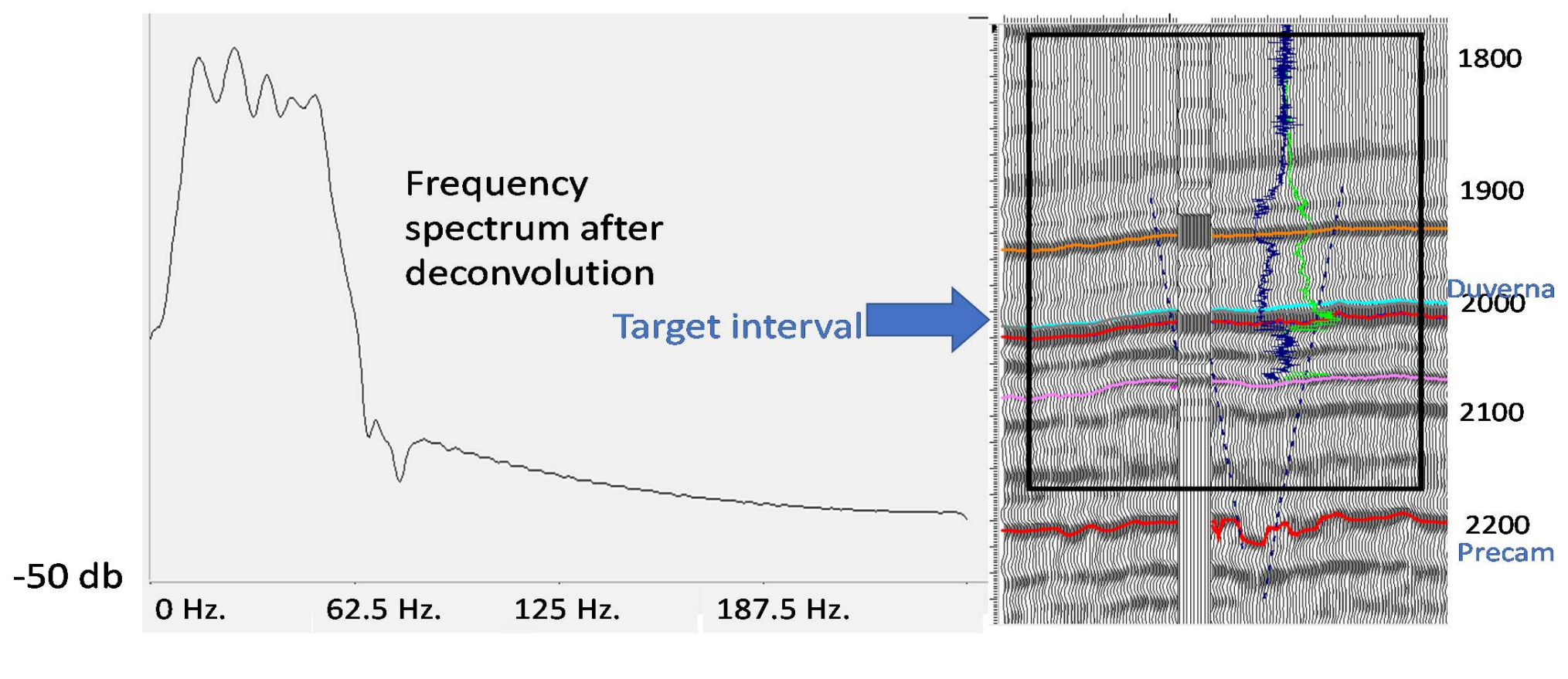
An illustration of the passive and active seismic sources. The passive seismic event can be thought of as the one-way equivalent of a reflected seismic event coming from the same depth. Attenuation effects will be similar in that the seismic signal travels through the same media on its way to the geophone recording array.



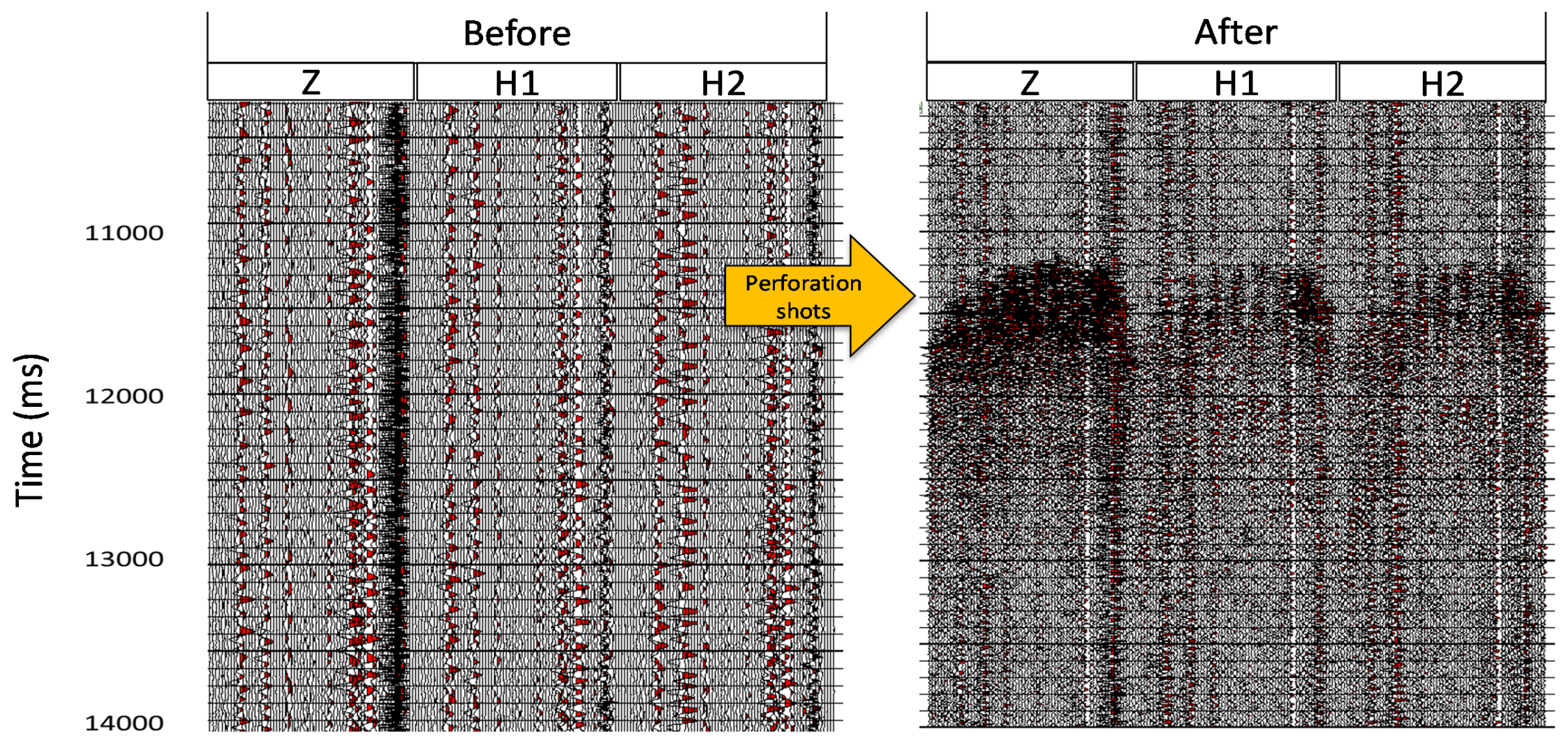
Following spiking deconvolution, zero phase deconvolution brings the data to zero phase

Time event picking becomes a much simpler operation

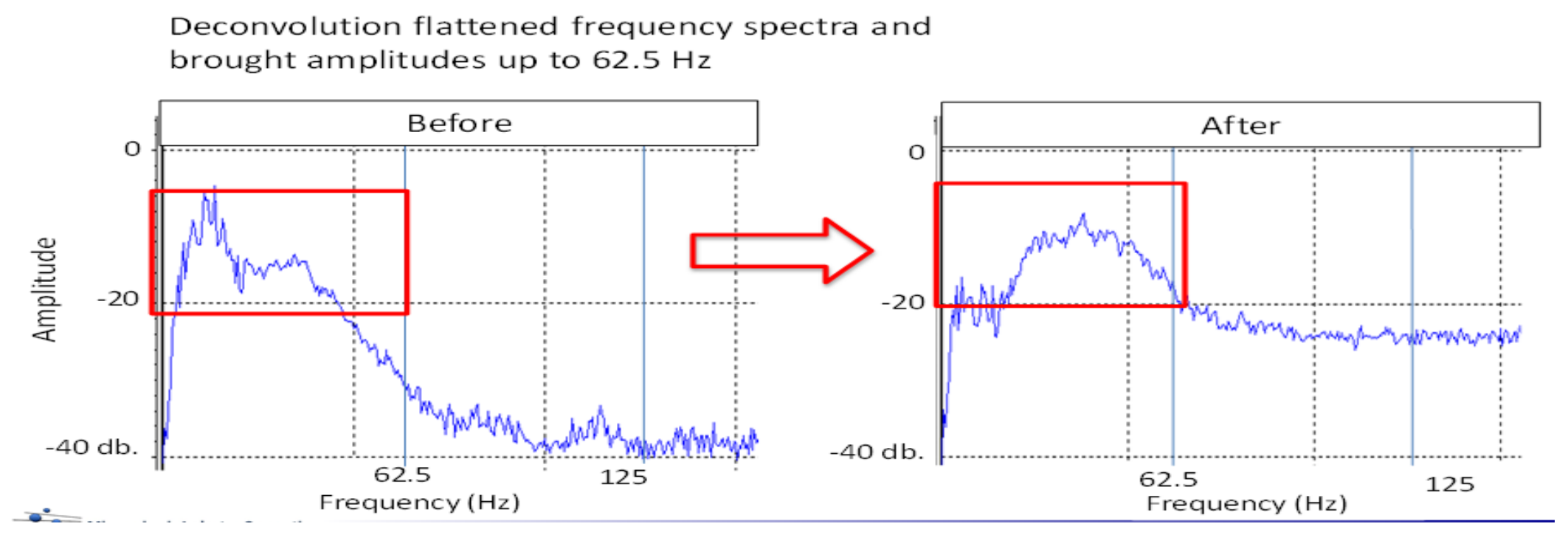
A schematic diagram of the output of zero phase deconvolution, and how seismic events are picked on the zero phase data. The onset of a seismic event is correlated as the seismic event (red dot); the deconvolution converts the data to zero phase, such that the event is picked on the maximum amplitude.



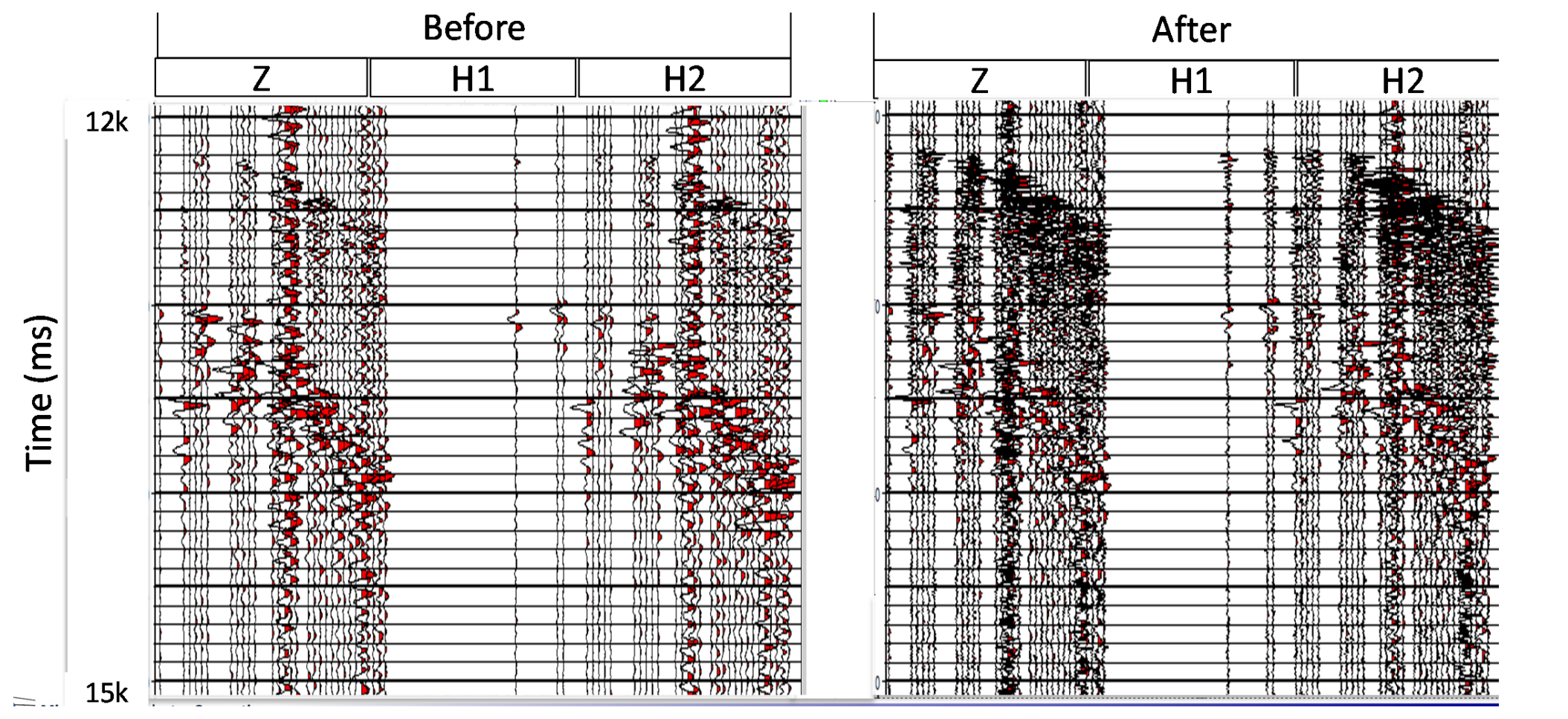
A cross section of seismic reflection data showing the spectrum of the seismic data calculated from the interval shown in the box. The spectra closely matches that of the induced seismic data.



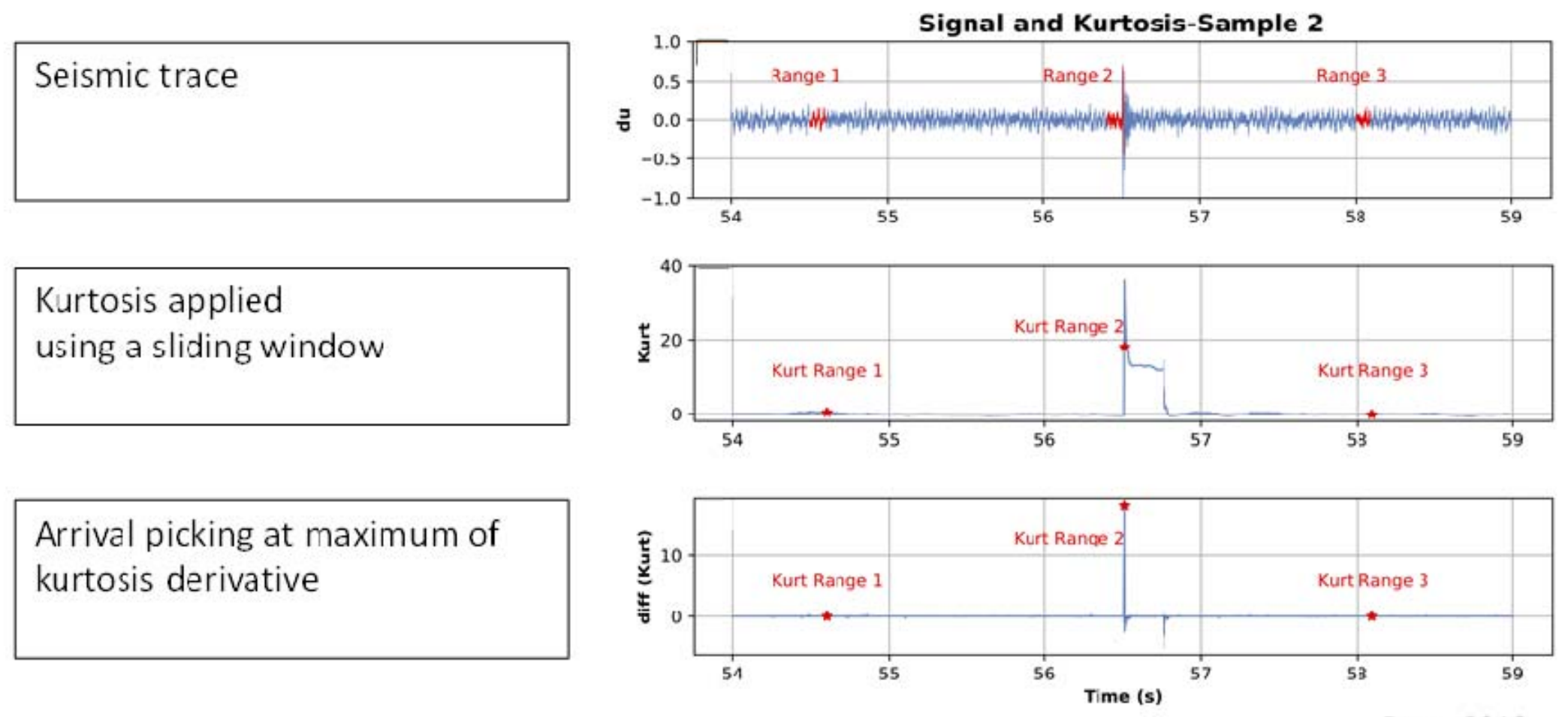
A continuous seismic record shown before and after processing. The data shown is the vertical components, Z, H1 and H2 components. The arrow points to a perforation shot, now visible.



A spectral analysis of the 60 second record from the above figure, before and after deconvolution. The effect of the spiking (Weiner) deconvolution is to balance the frequency spectra.



Seismic records sorted in offset distance with respect to a seismic event before and after deconvolution. There is a noticeable improvement in the P arrival (12500 ms.), there is no obvious improvement in the S arrival, although the signal is present at 13000 ms.



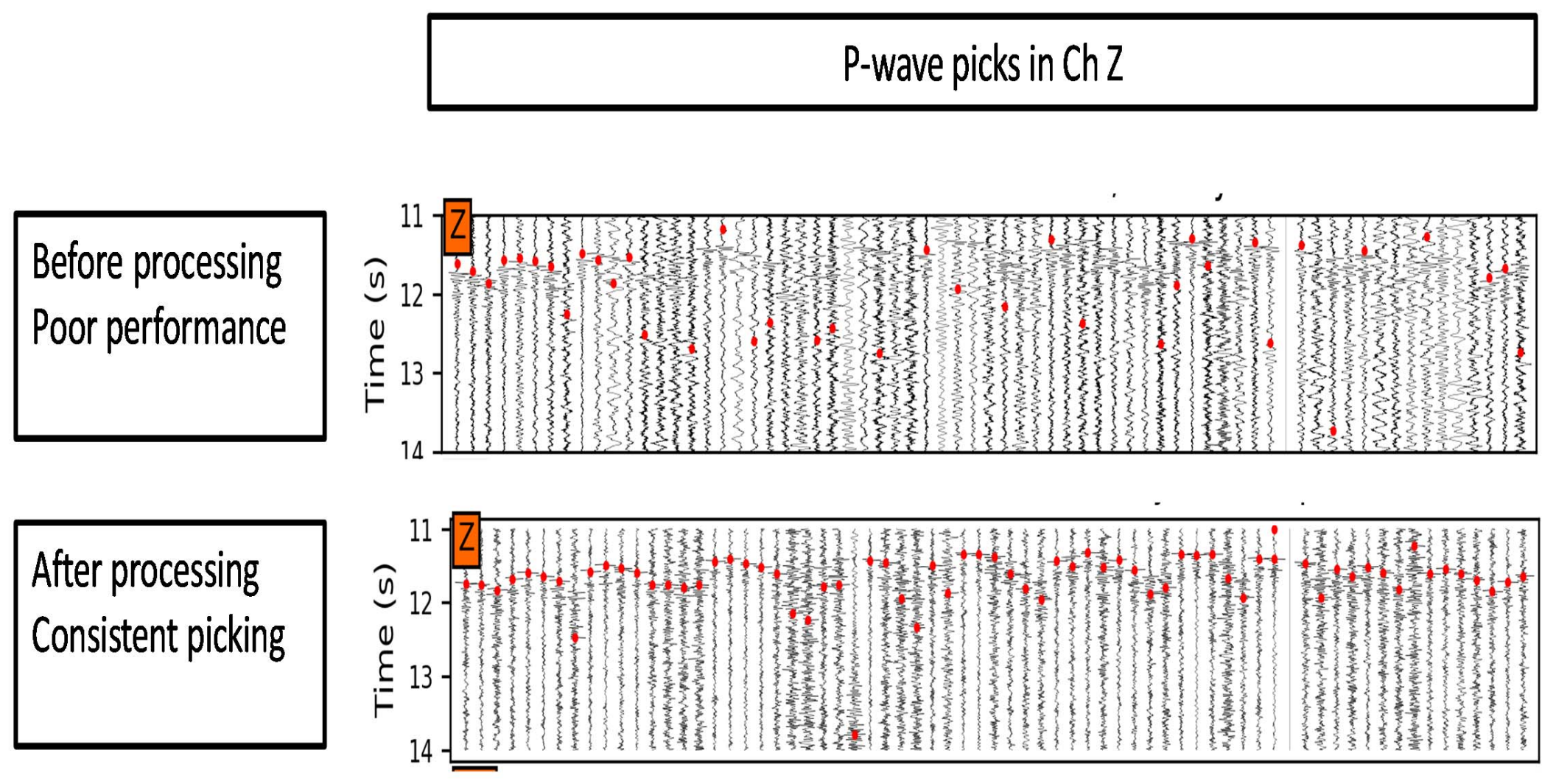
Seismic trace

Kurtosis applied using a sliding window

Arrival picking at maximum of kurtosis derivative

Paes, 2018

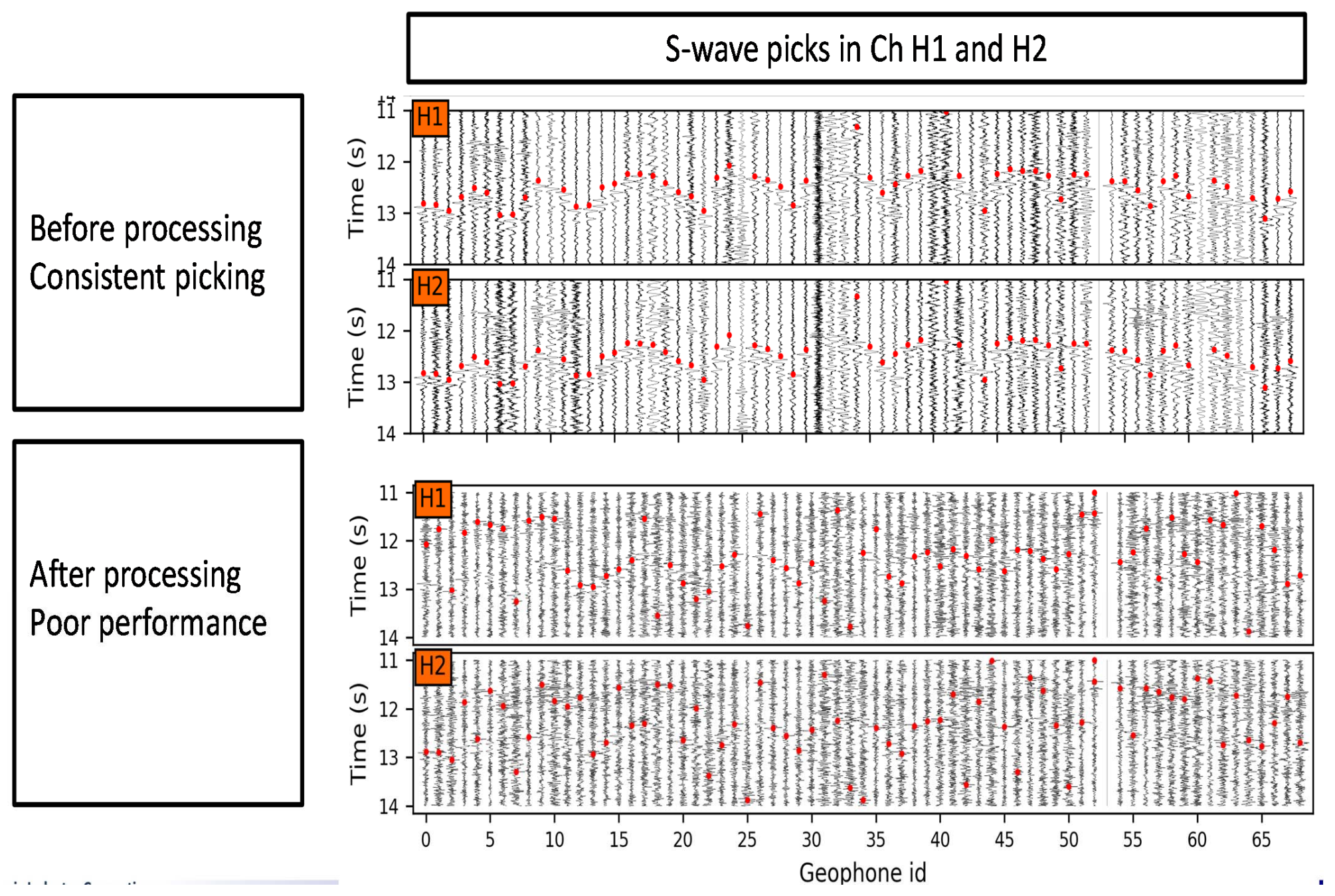
The kurtosis picking algorithm uses a time ranges derived from known seismic events (pilot trace) and uses them to detect events on the continuous record. This method is used in the examples shown hereto detect P and S arrivals.



Before processing Poor performance

After processing Consistent picking

An example of a raw seismic record showing arrival picks using differential kurtosis on P arrivals algorithm (ATP, upper panel), and the deconvolved record (lower panel). There is a significant improvement in the picking of the P wave arrivals in the deconvolved data.



Before processing Consistent picking

After processing Poor performance

An example of the same record shown below after processing, this time displaying the H1 and H2 components. The processed records have been picked for events using ATP maximum seismic amplitude, the unprocessed data delivered better picking results than the deconvolved data.

CONCLUSIONS

Reflection seismic data processing has useful applications in the conditioning of continuously recorded seismic data for microseismic monitoring. Processes such as deconvolution, filtering and scaling can enhance the signal to noise ratio and improve the ability of auto picking algorithms to detect events. The results obtained from the P wave arrivals show considerable improvement in identifying P wave arrivals, particularly in noisy data. The processing flow used here may not be suitable for S arrivals. It is possible that most of the S wave energy resides in the lower frequency band (around 10 Hz. or lower).

FUTURE WORK

A process specifically designed to enhance S arrivals will be developed. Zero phase deconvolution without the spectral balancing may be more suitable for the S wave response. Additional trace to trace techniques such as surface consistent deconvolution, FX and FK filtering may also be applied, as well as instrument compensation.

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